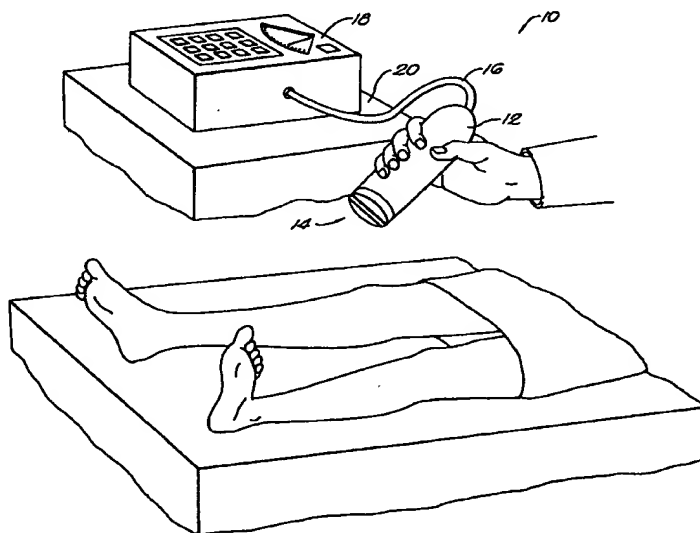


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(54) Title: HAIR FOLLICLE DEVITALIZATION BY INDUCED HEATING OF MAGNETICALLY SUSCEPTIBLE PARTICLES**(57) Abstract**

Apparatus, methods, materials and systems for devitalizing hair follicles are disclosed in which magnetically susceptible particles are applied to a skin segment in a manner whereby the particles are deposited within the hair follicles and then subjected to a varying magnetic field to induce localized heating in the proximity of the particle, thereby devitalizing at least one component of the hair follicle to inhibit further hair growth.

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Hair Follicle Devitalization**By Induced Heating of Magnetically Susceptible Particles****Background of the Invention**

The technical field of this invention is the removal of hair and inhibition of hair regrowth by devitalization of certain hair structures within hair follicles.

Individual hair follicles comprise a bulb or cavity below the surface of the skin, from which a body of soft keratin is extruded. This shaft of keratin hardens as it passes through the bulb and ultimately protrudes from the skin surface as a "hair." A small cellular structure at the bottom of the cavity, the papilla, together with ancillary germinative structures, is responsible for the extrusion of the keratin which eventually forms into a hair. Permanent hair removal requires devitalization of the papilla or the structures that surround it.

The removal of body hair, a process commonly known as depilation, has been practiced with varying degrees of success for centuries by diverse methods and devices. For example, hot wax can be applied to a skin surface and allowed to harden around body hairs. Once the wax has hardened, it can be removed as a sheet, taking with it those hairs that have been entrapped by the wax. Typically, this is not a permanent process because the removal of the hair shaft does not prevent the regrowth of new hair from the shaft.

Various chemical depilatories have been used to remove hair. Typically these chemical agents are caustic, e.g., sodium hydroxide and the like, which makes the treatment process painful. Moreover, chemical depilatories are often not very effective.

Another approach to depilation is the use of electrical currents to destroy the delicate structures of the hair root. For example, U.S. Patent No. 5,049,148 issued to Mehl discloses an electrical device of this nature. Similar devices, generally known as "electrolysis" devices have been used in various forms, with and without the assistance of chemical adjuvants.

5 However, electrolysis is time consuming because the electrical current must be applied to each hair follicle individually.

10 An alternative approach for permanently impairing regrowth of many hair follicles at once is disclosed in U.S. Patent 5,470,332 issued to Mehl et al. which involves the application of a conductive material to the skin's surface and then applying an electric current to this conductive layer.

15 Most recently, a number of techniques for photocoagulation of the delicate hair structures by laser irradiation have been disclosed. For example, U.S. Patent No. 5595568 issued to Anderson et al., U.S. Patent No. 4,388,924 issued to Weissman, et al., and U.S. Patent No. 5,059,192 issued to Zaias disclose such laser irradiation techniques.

20 In addition, U.S. Patent 5,425,728 and U.S. Patent 5,226,907 issued to Tankovich disclose laser techniques in which the hair follicles on a section of skin are first contaminated with a substance (i.e. carbon particles) that has high absorption of light within a specific frequency band. The skin is then illuminated with such light, typically from a laser source, to heat the contaminating substance and kill the follicles or skin tissue feeding the hair root.

25 None of the processes described above are totally effective in depilating skin. There exists a need for better and more effective techniques. Accordingly, better methods and devices for hair removal would satisfy a long-felt need in the art.

Summary of the Invention

30 Apparatus, methods, materials and systems for devitalizing hair follicles are disclosed in which magnetically susceptible particles are applied to a skin segment in a manner whereby the particles are deposited within the hair follicles and then subjected to a varying magnetic field to induce localized heating in the proximity of the particle, thereby devitalizing at least one component of the hair follicle to inhibit further hair growth.

5 In one aspect of the invention, devices are disclosed which generate a time varying magnetic field and apply such field to a region of a patient's skin that has been treated with magnetically susceptible particles.

10 In one embodiment, the apparatus can include a source of alternating electric current that is applied to one or more coils surrounding at least a portion of a partially open ring-ferrite structure; the structure having an open gap adapted to engage a region of a subject's skin into the follicles of which magnetically susceptible particles have penetrated. Each electrically conductive coil structure is also electrically coupled to a capacitor, such that the coil and capacitance define a resonant circuit, whereby, upon
15 application of an electrical current to the coil, a magnetic field is formed in the gap which heats the magnetically susceptible particles within the hair follicle to induce depilation. The gap can range from about 1 millimeters to about 50 millimeters, more preferably from about 3 millimeters to about 15 millimeters.

20 Various other designs can be employed to deliver the time varying magnetic field to the target hair follicles. The ferrite structure need not be a simple ring but can take alternative geometric shapes designed to concentrate the magnetic field at the desired locus. A plurality of magnetic field guides can also be used. Alternatively, quasi-spherical emitters can be designed to create a similar magnetic field concentration.
25 In addition, ferrite structures can be replaced by other magnetic field guides or concentrators, such as magnetic metallic glasses and ferro-magnetic alloys. In some applications, a simple electromagnetic field generator alone can serve as a source and guide or concentrator to deliver a varying magnetic field to the desired area.

30 In an embodiment described in detail below, the field is generated by a resonant circuit to which a voltage is applied and a driver comprising one or more power transistors is employed to provide electronic impulses in synchrony with the frequency of the resonant circuit, thereby offsetting the energy dissipated by operation. The magnetic field guide (e.g., an open ferrite ring structure) can be readily incorporated
35 into a handpiece which permits the clinician to manually apply the magnetic field to the

5 treatment region. The open ring of ferrite is configured such that the gap is disposed at the tip of the handpiece in order to applied the magnetic field to the target tissue region. The handpiece can further include a coolant to extract the energy which is dissipated as heat with the field guide. The power source, driver electronics, a control
10 microprocessor, manual controls, coolant circulator and various other auxiliary systems can be housed in a remote structure to which the handpiece is connected by one or more cables providing electrical energy and/or coolant and any auxiliary functions to the handpiece.

15 In another aspect of the invention, methods are disclosed to induce hair depilation by magnetic-field heating of magnetically susceptible particles deposited within hair follicles. In one method, the hair shafts in a treatment region optionally can be first extracted by wax treatment and/or tweezers. (An anesthetic agent, such as Novocain can be applied before or after this step.) Optionally or alternatively, the skin can be cleaned to open the patient's pores. A slurry of magnetically-susceptible
20 particles is then applied to the treatment region in a manner that facilitates deposition of such particles in to the empty spaces of the hair follicles. Deposition into the follicles can be accomplished simply by manual rubbing, or with the aid of mechanical or pressurizing instruments. (For example, a vibrating applicator (e.g. an ultrasound applicator operating at about 10 – 20 kHz) can be used or a pressurized fluid (liquid or
25 gaseous) carrying such particles can be applied to a sealed region.)

Following application of the particles and deposition of such particles into the hair follicles, the skin surface can be cleaned of any excess particles or applicator fluid. The treated region is then ready for application of the alternating magnetic field. The
30 time-varying field induces localized heating of the particles, a portion of which will be located near enough to the papilla or other delicate structures to devitalize the hair follicle. It may also be desirable to heat the patient's skin (or monitor the skin temperature) to reduce the amount of energy that the particles need to deliver in order to kill the cells of the follicle.

5 The particles can then be removed (or left to be naturally cleared or metabolized by the patient's body). The use of iron oxide particles is particularly advantageous because such materials have very low toxicity and can be absorbed by the body and used as nutrients. When removal is desired, mechanical suction, aided by vibration or intermittent flushing (e.g., with water, saline or other solvents), can be employed.
10 Alternatively, magnetic forces can be applied to extract the magnetic particles.

 Such methods can further include the step of protecting any sensitive metallic implants or prostheses before the application of the magnetic field. For example, dental fillings or metal orthodontic braces may interfere with the removal of facial hair. Such
15 structures can be protected by one or more mouth guard-type insulators which are fitted to surround any metallic dental work. The mouth guard is preferably flexible and comprises a material that possesses high magnetic shielding properties. For example, the mouth guard can be made from a plastic coated steel (or other metallic conductor).

20 In yet another aspect of the invention, compositions are disclosed for effecting magnetic field heating of hair structures to induce depilation. The compositions include magnetically susceptible particles having an average size sufficiently small to allow penetration of at least a portion of said particles into the follicles on the target skin segment and further having sufficient magnetic properties to induce localized heating in
25 the presence of variable magnetic field following penetration into the hair follicle to devitalize at least one component of the hair follicle and thereby inhibit further hair growth from within the follicle.

 The compositions can include a slurry of particles having an average particle
30 size ranging from about 5 Angstroms to about 100 micrometers in diameter, or more preferably ranging from about 50 Angstroms to about 10 micrometers in diameter. The compositions can further include particles of a lubricant material, such as surfactants, or the particles can be coated with a lubricating material, such as a surfactant, or silicone, hyaluronic compositions, dextran or combinations thereof. Such compositions can be
35 delivered to the skin as either dry slurries or as part of fluid delivery compositions.

5 Fluid delivery compositions according to invention can further include a fluid carrier that enhances penetration of the particles into the hair follicles. The fluid carriers can be lotions (e.g., aqueous or non-aqueous liquids or liquid solutions, as well as emulsions, suspensions) or gaseous mixtures. Liquid lotions can include surfactants, pore opening agents or transdermal penetrating enhancing agents. Gaseous carriers can include air or other gas mixtures, typically applied to the skin under pressure to drive the magnetically susceptible particles into the skin pores and, in particular, into the lower regions of the hair follicles. Gels or semi-solid materials, such as polyvinyl alcohols, which soften or liquefy under application pressure can also serve as a delivery medium for the particles.

15 In yet another aspect of the invention, systems or kits are disclosed for depilating hair, including compositions for effecting magnetic field heating of hair structures to induce hair depilation and one or more of the following components: topical anesthetics, wax compositions for hair extraction, apparatus for applying a variable magnetic field to a skin region, particle/lotion applicators, penetration enhancing devices, particle removal devices and protective shield-structures.

25 The magnetic field generating apparatus can include a source of alternating electric current, a partially-open ring-ferrite structure; the structure having an open gap adapted to engage a region of a subject's skin and permitted an electrically conductive coil structure surrounding at least an portion of the ferrite structure and electrically coupled to the source of alternating current through a capacitance, such that the coil and capacitance define a resonant circuit, whereby, upon application of the compositions containing magnetically susceptible particles to hair follicles within the skin region and the application of an electrical current to the coil, a magnetic field is formed in the gap which heats the magnetically susceptible particles to induce depilation.

35 The terms "depilation" and "devitalization" as used herein are intended to encompass the devitalization of hair follicles, the destruction of hair papilla (and/or associated structures), inhibition of future hair growth, or interference with any portion of the normal hair cycle. The process of depilation as taught in the present invention

5 describes a variety of hair removal processes included, *inter alia*, the destruction (or substantial deactivation) of hair papilla and/or the epithelium columns that connect a growing or mature hair to the papilla; closure or modification of the hair follicle to preclude hair foliation; as well as simply the removal of the hair from the follicle. Such depilation or devitalization processes can be directed to single hair follicles or,
10 preferably to larger areas of skin to treat a region including more than one follicle, it being understood that depilation or devitalization over any region of skin may only be partially successful during an initial treatment according to the invention and a plurality of treatments may be necessary to obtain a desired result of general hair removal from a region of a subject's body.

15 The term "magnetically susceptible particles" as used herein is intended to encompass a wide range of either magnetic or electrically conductive materials, which are of a size that permits their passage into hair follicles. The magnetic or electrically conductive materials which can be used herein include any non-toxic metal, including
20 gold, silver and palladium, as well as magnetic metals such as iron, nickel and cobalt and their alloys, other conductive or magnetic metal alloys and metallic compounds which likewise possess electrical or magnetic properties. One such compound, magnetite, a magnetizable iron oxide having the general formula of Fe_3O_4 , has proved to be particularly useful in experimental trials, but various other materials may prove to
25 be more advantageous or useful for particular applications. The term "magnetically susceptible particles" encompasses not only materials that are inherently magnetically susceptible but also materials which become magnetically susceptible when deployed in the *in vivo* environment. The particles can be as small as individual molecules or ions. For example, spin transition polymers currently being developed for ultra dense
30 magnetic memory devices may be useful. On exemplary compound magnetically susceptible particles can have the general formula: $\text{Fe-R-I} \cdot n\text{H}_2\text{O}$, where R is a triazol, I is a cation or anion and $n\text{H}_2\text{O}$ is noncoordinated water.

35 Typically, the average size (i.e., the diameter or length of the longest dimension for non spherical shapes) of the magnetically susceptible particles can vary from about 5

5 Angstroms to about 100 micrometers, and more preferably from about 50 Angstroms
to about 10 micrometers. The magnetically susceptible particles can be applied to the
skin as a powder, in a liquid or as part of a lotion. Within a particular powder, liquid or
lotion the size of the particles can range by more than one, or even two, orders of
magnitude; the only critical factor being that a sufficient number of the magnetically
10 susceptible particles should be capable of entering the hair follicle cavity and lodging in
positions that facilitate depilation.

 The term "magnetically-susceptible particles" is also used herein to encompass
coated particles as well as molecular structures that incorporate any of the above
15 referenced elements or compounds. Coating materials can include surfactants,
polysaccharides, such as dextran, as well as ficolls, silicones, chondroitin sulfates,
dextrane sulfates, laurates, inulins, and xylans. Molecular structures can include
ferritins, hemosiderins and similar materials which comprise a spherical protein cage in
which iron is stored (e.g., in the form of iron(III)oxyhydroxide). Colorants can also
20 form part of the particles.

 A presently preferred embodiment comprises a coated magnetite powder. Such
powders are available from a variety of sources. For example, magnetite powders are
available from Ferrofluidics Corporation (Nashua, New Hampshire) and/or Toda
25 America Incorporated (Schaumburg, Illinois). As noted above, the average size of
individual magnetite particles can vary in size from about 10 angstroms to about 100
micrometers in diameter. The initial susceptibility of such particles ($4\pi M/H$) can range
from about 0.1 to 0.9 EMU/gauss/gFe.

30 It should be appreciated that the formula Fe_3O_4 for magnetite is an empirical
formula. Magnetite is more precisely described as a crystalline metal oxide having two
components: FeO and Fe_2O_3 . Two different valence iron ions occupy specific sites in
the crystal structure. The A metal is Fe+2 and the B metal is Fe+3. The arrangement
causes a transfer of electrons between the different irons in a structured path or vector.
35 This electric vector generates the strong magnetic field associated with native magnetite

5 ores. Although magnetite is a presently preferred material for the magnetically susceptible particles of the present invention, various other materials may also be useful, including, for example, iron hydroxides, cobalt-Fe₃O₄, barium ferrites, and metallic iron particles.

10 Superparamagnetic particles (e.g. with initial susceptibilities greater than 0.5 EMU/gauss/gFe and/or negligible coercivity) can also be used. One such composition, a gamma ferric oxide, is disclosed in U.S. Patent 5,411,730 issued to Kirpotin et al on May 2, 1995 and incorporated herein by reference. This patent also describes various techniques for coating particles to form ferroliposomes and the like which can be
15 generally applicable to the present invention.

Colloidal suspensions of magnetite, coated with one or more surfactants, are also available from Ferrofluidics Corporation. More generally, suspensions of magnetically-susceptible particles can be formed with water, water/alcohol mixtures or
20 multiphasic liquids as the carrier. Suspensions useful in the present invention can vary in viscosity from about 1 centipoise to about 100,000 centipoise with magnetite concentration varying from about 0.5 volume percent to about 20 volume percent (yielding magnetic flux densities from about 20 gauss to about 1,000 gauss). One exemplary composition can be formed by coating magnetite particles with a cationic
25 surfactant and suspending such coated particles in a water/ethanol mixture. In other applications, anion, amphoteric or non-ionic surfactants may be preferred.

Lotions useful in the applying the magnetically susceptible particles to the skin can include aqueous and/or organic (e.g., oily or alcohol) fluids, as well as emulsions
30 having both aqueous and non-aqueous phases. The lotions are preferably chosen because of their ability to promote penetration of the magnetically susceptible particles into the cavities of the hair follicles. In some applications a proper balance of hydrophobic and hydrophilic components may be optimal in assisting penetration. In other applications the addition of an electrically charged component or the presence of
35 chemical additives with chemical moieties that present a surface electrical charge can be

5 useful. In yet other embodiments, it can be useful to employ lubricants such as silicones or hyaluronic compositions, either as coatings for the particles or as additional components of the lotion to enhance lubricity. Alternatively, chemical agents that induce expansion of the hair follicle openings can be useful.

10 Thus, the term "lotion" as used herein is intended to encompass solutions, such as aqueous and organic solvent solution and well as suspensions, emulsions and the like which serve as carriers for a magnetically susceptible particle or plurality of such particles. In one embodiment the lotion can be an aqueous solution including a surfactant. In another embodiment, the lotion can be a mixture of water and alcohol or
15 a mixture of water and aliphatic liquid. Alternatively, the lotion can be an oil alone or in conjunction with an emulsifying agent that ensures a uniform distribution of magnetically susceptible particles. The lotions can further include colorants, transdermal enhancing agents, as known in the art, and pore opening agents, likewise known in the art, to facilitate hair follicle penetration.

20 In the present invention, the application of the varying magnetic field to the magnetically susceptible particles induces rapid and extremely localized heating in the region of immediately surrounding the particles. Although no one theory of explanation may be entirely correct in analyzing this heating effect, it appears that the orientation
25 and reversal of domain polarities in magnetic materials as well as the creation of eddy currents in conductive materials both play a role in the superheating of the particles. When a particle is disposed within the hair follicle, the heat generated by the particle is sufficient to destroy or devitalize the follicle's internal structures necessary for hair growth.

30 "Alternating current" as used herein is intended to encompass not only sinusoidal waveforms, but also various other waveforms, such as pulsed, square wave, ramped, saw tooth, chirped waveforms and the like. The particular shape of the waveform is largely irrelevant so long as it can induce a variable magnetic field in the
35 target skin region where magnetically susceptible particles are heated to achieve the

5 desired depilatory effect on hair follicles. Similarly, the term "variable field" is intended to encompass not only reversals of polarization but also pulsed fields and any other magnetic field that changes over time in a manner that permits the transfer of energy from the power supply to the magnetically-susceptible particles. The frequency of alternation or variation can vary from about 1 kilohertz to about 10 gigahertz,
10 preferably from about 10 kilohertz to about 100 megahertz, and, in some applications, it may be preferable to vary the frequency from about 20 kilohertz to about 20 megahertz or from about 50 kilohertz to about 3 megahertz.

15 Ferrite cores useful in channeling magnetic field lines can be obtained from various sources including Magnetics, Inc. (Butler, PA); TDK Corporation (Tokyo, Japan) or U.S. Philips Corporation (New York, New York). Ferrites useful in the present invention encompass ferromagnetic compounds and iron-containing compositions generally (including ferromagnetic alloys and magnetic metal glasses) which exhibit high magnetic permeability and also high electrical resistivity. One
20 example of such materials is the 3F3 Ferrite manufactured by U.S. Philips Corporation. The ferrite preferably is capable of generating a magnetic field of at least 0.02 Tesla and, more preferably, a field greater than about 0.3 Tesla. In some applications a ferrite core may not be necessary and instead can be replaced by an air coil (e.g. a torroidal coil) or other arrangements that can serve as magnetic field guides.

25 The term "Curie temperature" or " T_C " as used herein is used as a measurement of temperature (or temperature range) where magnetically susceptible materials undergo a rapid change in their properties. For many of the magnetically susceptible materials useful in the present invention it represents a plateau point beyond which
30 additional exposure to the variable magnetic field will not induce significant additional heating effects. In applications where a lotion containing a substantial quantity of magnetically susceptible particles is applied and penetrates into the skin, it is desirable that the particles themselves exhibit a high enough Curie temperature to devitalize the follicle by local heating effects but not induce significant thermal damage to
35 surrounding dermal structures. In some embodiments of the present invention, the

5 Curie temperature of the magnetically susceptible particles useful in the present invention is preferably greater than about 45°C, more preferably greater than about 60°C, and most preferably greater than about 75°C, but less than 600°C.

10 However, in other applications of the invention where the heating is very localized, the Curie temperature of the particles can be much greater, so long as the total application of depilating energy does not have significant adverse effects on surrounding tissue regions. Magnetite is an example of a very high Curie temperature material that is, nonetheless, particularly useful in certain applications of the invention.

15 The invention will next be described in connection with certain illustrated embodiments; However, it should be clear that various changes and modifications can be made by those skilled in the art without departing from the spirit and scope of the invention.

20 **Brief Description of the Drawings**

The invention may be more fully understood from the following description when read together with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a system according to the invention for magnetic devitalization of hair follicles in a skin segment;

25 FIG. 2 is a more detailed cross-sectional schematic illustration of an apparatus for delivering a varying magnetic field according to the invention;

FIG. 3 is a schematic diagram of a driver circuit for the apparatus of FIG. 2;

30 FIGS 4A - 4E illustrate a method of hair follicle devitalization according to the invention; FIG 4A shows an optional initial step of removing hairs from a skin surface; FIG. 4B illustrates the application of magnetically susceptible particles to the skin surface; FIG 4C illustrates the migration of magnetically susceptible particles into the hair follicles and the removal of any excess magnetically susceptible particles and/or carrier fluid from the skin surface; FIG. 4D shows the application of a varying magnetic field to induce heating of the particles; and FIG. 4E illustrates the optional further step of removing the particles from the follicles following treatment;

35 FIG. 5 illustrates an apparatus for applying magnetically susceptible particles to follicles in a skin segment;

5 FIG. 6 illustrates an alternative apparatus for applying magnetically susceptible particles to follicles in a skin segment;

 FIG. 7 illustrates another alternative apparatus for applying magnetically susceptible particles to follicles in a skin segment;

10 FIG. 8 illustrates an apparatus for removing magnetically susceptible particles from follicles in a skin segment;

 FIG. 9 illustrates an alternative apparatus for removing magnetically susceptible particles from follicles in a skin segment; and

 FIG. 10 illustrates a protective cover for dental work when removal of facial hair is desired.

15 Detailed Description

 In FIG. 1, a system 10 for magnetic follicle devitalization is shown comprising a handpiece 12 which houses a magnetic field generating open-ring ferrite structure. The open-ring is oriented such that the opening in the ring forms a gap 14 at the distal end of handpiece 12. The handpiece is connected via conduit 16 to a controller 18 and an auxiliary housing 20 (which can include driver electronics, a control microprocessor, manual controls, a coolant circulator and various other auxiliary systems).

25 In FIG. 2, the handpiece 12 of FIG. 1 is shown in more detail including the ferrite ring structure 30, an inductive coil 32 which is wrapped around the ferrite core and a capacitor and/or other electronics 35. Power to generate a magnetic field within the ferrite 30 can be supplied from the housing 20 (shown in FIG. 1) via electrical cables 40. The handpiece can also incorporate an internal cooling chamber 34 which is supplied with coolant via a coolant source conduit 36. The coolant circulates within the chamber 34 to extract heat which otherwise would build up in the ferrite ring 30. Heated coolant can be withdrawn from the handpiece via a coolant exit conduit 38 for recycling within the housing or disposal. The electrical cables as well as the coolant supply and extraction conduits can all be encased within a single tubing 16 (or, alternatively, separate cables can be employed for electrical power and coolant delivery). The shell 28 or rim 29 of the handpiece 12 can also be used to heat the patient's skin. The rim 29 can also include a marker mechanism (e.g., an ink application) 27 which serves to delineate areas which have been treated.

5 The electronic circuitry 35 within the instrument (in cooperation, if necessary, with an auxiliary processor within housing 20) can also include an electronic sensor for metallic implants such as dental work (e.g., metallic fillings and/or orthodontic braces) that may need to be protected if the treatment region is in close proximity to such an implant.

10 In FIG. 3, an electrical schematic diagram of a driver circuit for the magnetic field-generating ferrite ring 30 is shown comprising the inductive coil labeled "L₁" in the drawing. As shown, it consists of 6 turns of wire about the ferrite torroid 30 (shown in phantom). The inductor L₁ is connected to capacitor C, as shown, and supplied with a
15 current via a center tap. Power transistors T₁ and T₂ serve to inject additional energy into the circuit as energy is lost (as heat) in the ferrite core 30 and/or other components of the circuit. In one illustrative embodiment, about 2 amperes is supplied via choke L₂ to the center tap. The choke L₂ can have an inductance of 350 microhenries and the 6
20 turn inductor L₁ can have an inductance of about 3.5 microhenries. The capacitor C can have a capacitance of about 0.08 microfarads. Power transistors T₁ and T₂ are N-channel MOSFET transistors (Model No. IRFP460LP) available from the International Rectifier Corporation.

25 Together the inductance L₁ and the capacitors C form a resonant circuit with approximately 70 amperes of current flowing back and forth. Preferably, the resonant circuit of the coil L₁ and capacitance C has a Q factor over 10. The opening and closing of transistors T₁ and T₂ are timed to synchronize with the resonant frequency of the LC circuit. The ferrite core can be a open-toroidal structure (with a gap of about 7 mm) made, for example, from 3F3 ferrite material available from the U.S. Phillips Corporation.
30 This current-fed resonant push-pull circuit serves to generate an oscillating magnetic field within the ferrite ring 30 (and across the gap) at the same frequency as the resonant LC circuit.

35 All matter exhibits magnetic properties when placed in an external magnetic field. Even non-magnetic metals, such as copper and aluminum, are affected by the presence of a magnetic field. Materials that are attracted to the pole of a magnet are classified as paramagnetic, while those that are repulsed are classified as diamagnetic. Materials, such as iron, that exhibit a very strong attraction towards the pole of a magnet are further classified as ferromagnetic. Whether a substance is paramagnetic or diamagnetic depends

5 primarily on the presence or absence of free magnetic dipole moments in the material's constituent atoms.

10 Because paramagnetic materials have free magnetic dipole moments, the presence of a magnetic field will induce alignment of the normally randomly aligned moments (or domains) of the material. When an alternating magnetic field is applied to such materials, the dipoles will attempt to reverse their orientation. As the dipoles are cycled back and forth, heating occurs at the microscopic level until a certain temperature (dependent on the material) is reached. This temperature is typically referred to as the Curie temperature and represent a plateau for many materials at which they exhibit minimal responses to further magnetic excitation.

20 In one embodiment the present invention can take advantage of this property of magnetically susceptible materials by "tuning" the frequency and duration of the varying magnetic field to ensure that the magnetically susceptible particles are rapidly brought to their Curie temperature and held there only for a period of time sufficient to induce apoptosis of the hair papilla and/or other hair structures.

25 In another embodiment of the invention, heat is generated by interaction between the magnetically susceptible particle and a fluid carrier. When such a magnetically susceptible particle is exposed to an alternating or rotating magnetic field while it is in a fluid, the particle will be induced to rotate or swing into alignment with the field. The mechanical friction between the particle and the fluid dissipates the field energy as heat in fluid surrounding the particle. The optimal frequency for heating will depend upon the particle's magnetic movement, its moment of (rotational) inertia and, to some extent, the viscosity of the surrounding fluid. At frequencies above the optimal frequency (for a particular particle and fluid composition) the moment of inertia for individual particles will inhibit heating because the particles will be unable to swing in response to such high frequencies.

35 FIGS. 4A-4E illustrate a method of hair follicle devitalization according to the invention. In FIG. 4A, hair shafts 41 are removed from the lumens or cavities 42 of hair follicles. The hair shafts 41 can be removed, for example, by the application of a hot liquid wax 44 and, after solidification, removal of the wax 44 from the patient's

5 skin. Alternatively, tweezers or other mechanical instruments can be employed to remove hair shafts from the treatment site.

10 In FIG. 4B, a slurry or lotion 45 containing magnetically susceptible particles 46 is applied to the surface of the skin 47. Following application, a portion of the slurry or lotion (and the magnetically susceptible particles) penetrate into the individual hair follicles as shown in FIG. 4C. Once penetration is achieved, the excess slurry or lotion can be removed from the patient's skin surface 47.

15 In FIG. 4D, the magnetic field generating apparatus of the present invention is applied to the skin. As illustrated, a ferrite ring structure 30 (shown in phantom) is pressed against the skin causing a slight indentation and squeezing the treatment area into the gap region 48 such that the magnetically susceptible particles 46 are subjected to the magnetic field 48. (It should be appreciated that the magnetic field generator can engage the skin without direct contact. In some embodiments, engagement can be
20 achieved by simply aiming the magnetic field generator at the target skin region. The term "engage" as used herein is intended to encompass both physical contact and non-contact relationships -- in which the magnetic field is applied by an instrument at some distance from the treatment area.) The alternating current of the applicator causes an varying magnetic field in the gap region 48 and induces localized heating of particles
25 46. One or more particles disposed within the cavity of the follicle is sufficient to devitalize it by heating effects, as shown in FIG. 4D.

30 In FIG. 4E the magnetically susceptible particles 46 can be removed with a removal apparatus 49, employing either suction or magnetic forces to dislodge and detract the magnetic particles following treatment, as shown in FIG. 4E.

In FIG. 5, a applicator structure 50 is shown comprising a hand-held housing 52 and a source 58 of magnetically susceptible particles 46. Particles can be driven into the skin by pressure. The air or fluid pressure supplied by instrument 50 causes at least

5 a portion of the magnetically susceptible particles to penetrate into the cavities 42 of the hair follicles. A sealing rim 59 can also be incorporated.

10 In FIG. 6, an alternative applicator 50A is shown which includes a vibrating rim 62. The instrument 50A not only can apply air or fluid pressure to induce particle penetration but the vibration of rim element 62 further enhances the penetration of the magnetically susceptible particles 46 into the cavities 42.

15 In FIG. 7 yet another applicator 50B is shown in the form of a hand held reservoir 63 for magnetic particles 46 in a polymeric matrix 65. The applicator 50B can be similar in form and composition to deodorant sticks and employ a semi-solid or gel carrier (such as a polyvinyl alcohol) which changes viscosity upon application of pressure to release the particles into the follicle cavities.

20 In FIG. 8, a particle extraction device 70 is shown which employs a rim gasket (or oscillating ring element) 72 to isolate the region from which the magnetic particles will be extracted following therapy. The lumen of the instrument 70 can be connected to pump 76 supply suction or, alternatively, a combination of flushing and suction to facilitate particle removal.

25 In FIG. 9, yet another embodiment of a removal apparatus 80 is shown including not only a suction function but also a magnet 86 which can be either a permanent or oscillating electromagnet which further assists in the removal of the magnetically susceptible particles by magnetic attraction. This magnetic attraction function can, of course, be combined with either suction or flushing and/or mechanical
30 vibration of the skin to cooperate in the removal of the particles 46.

35 In FIG. 10 another auxiliary component of the invention, a protective covering 90 is shown. This protective covering 90 is specifically adapted to protect a patient's dental work (e.g., metallic fillings and/or orthodontic braces) during the removal of facial hair. The instrument 90 is shaped in the form of a mouth guard and has a curved

5 groove into which a patient's teeth can be inserted. (Although a single mouth guard for
an upper set of teeth is shown in FIG. 9, it should be clear that similar devices can also
be employed for protection of the patient's lower set of teeth and other forms can be
used to protect other portions of the patient's body.) Preferably, the instrument 90 is
10 made of a malleable plastic material and is filled internally with a substance (e.g., a
metal or other electrically conductive material) that effectively shields the teeth from
magnetic fields.

5

Claims

1. An apparatus for devitalizing hair follicles, comprising:
a magnetic field guide adapted to engage a region of skin; and
a generator for producing a varying magnetic field and applying the
varying field to the skin through the field guide,
whereby, upon application of magnetically susceptible particles to hair
follicles within the skin and generation of the varying magnetic field, the particles are
heated to devitalize the hair follicles.

10

15

2. The apparatus of claim 1 wherein the varying magnetic field has a
frequency ranging from about 1 kilohertz to about 10 gigahertz.

20

3. The apparatus of claim 1 wherein the varying magnetic field has a
frequency ranging from about 10 kilohertz to about 100 megahertz.

4. The apparatus of claim 1 wherein the varying magnetic field has a
frequency ranging from about 20 kilohertz to about 20 megahertz.

25

5. The apparatus of claim 1 wherein the varying magnetic field has a
frequency ranging from about 50 kilohertz to about 3 megahertz.

30

6. The apparatus of claim 1 wherein the apparatus further comprises
source of alternating electric current;
a magnetic field guide having an open gap adapted to engage a region of
a subject's skin

35

an electrically conductive coil structure surrounding at least an portion
of the magnetic field guide and electrically coupled to the source of alternating current
through a capacitance, such that the coil and capacitance define a resonant circuit,
whereby, upon application of magnetically susceptible particles to hair
follicles within the skin region and the generation of an electrical current in the coil, a

5 varying magnetic field is formed in the gap which heats the magnetically susceptible particles to induce depilation.

7. The apparatus of claim 6 wherein the magnetic field guide comprises a ferrite structure.

10 8. The apparatus of claim 6 wherein the ferrite structure comprises an iron-containing composition.

15 9. The apparatus of claim 6 wherein the ferrite structure upon application upon an electric current to the coil, the apparatus generates a varying magnetic field having a peak strength of at least 0.02 Tesla in the gap.

20 10. The apparatus of claim 6 wherein the ferrite structure upon application upon an electric current to the coil generates an magnetic field of at least 0.3 Tesla in the gap.

11. The apparatus of claim 6 wherein the gap in the ferrite structure is less than 50 millimeters.

25 12. The apparatus of claim 6 wherein the gap in the ferrite structure is adapted to pinch and hold a region of skin during treatment.

13. The apparatus of claim 6 wherein the resonant circuit of the coil and capacitance has a Q factor over 10.

30 14. The apparatus of claim 6 wherein the resonant circuit further comprises a power supply of at least 100 watts.

5 15. The apparatus of claim 6 wherein the apparatus further comprises a driver circuit in synchrony with the resonant circuit to inject additional energy into the resonant circuit to compensate for energy losses.

10 16. The apparatus of claim 15 in which the driver circuit further includes at least power transistor which is switched on and off in synchrony with the frequency of resonant circuit.

15 17. The apparatus of claim 1 wherein the apparatus further comprises a coolant chamber which extracts excess heat from the apparatus during use.

 18. The apparatus of claim 1 wherein the apparatus further comprises a shield which reduces electric field effects on the skin region.

20 19. The apparatus of claim 1 wherein the apparatus further comprises a heater element for heating the skin region.

 20. The apparatus of claim 1 where in the apparatus further comprises a handpiece which houses the magnetic field guide.

25 21. A method of devitalizing a hair follicle on a skin segment, comprising, applying magnetically susceptible particles to the skin segment in a manner whereby at least one magnetically susceptible particle is deposited within a hair follicle; subjecting said deposited particle to a varying magnetic field to induce localized heating in the proximity of the particle such that said heat devitalizes the hair follicle to inhibit further hair growth.

30

 22. The method of claim 21 wherein the method further comprises applying a slurry containing said magnetically susceptible particles to the skin segment such that penetration of the hair follicle occurs by infiltration.

35

5 23 The method of claim 21 wherein the magnetically susceptible particles are applied to the skin segment by applying a lotion containing magnetically susceptible particles onto the skin segment.

10 24. The method of claim 21 wherein the method further comprises initially removing the hair shafts from the follicles so that the cavities of the hair follicles are exposed.

15 25. The method of claim 24 wherein the step of removing the hair shafts further comprises applying a wax to the skin and then removing the wax with the hair shafts entrained therewith.

20 26. The method of claim 21 wherein the method further comprises applying a chemical hair defoliant agent prior in order to remove at least some the hair shafts prior to applying the magnetically susceptible particles.

 27. The method of claim 21 wherein the method further comprises applying a dermal pore-opening agent in order to enlarge the openings of the follicle cavities prior to applying the magnetically susceptible particles.

25 28. The method of claim 21 wherein the method further comprises applying a cleaning agent prior to applying the magnetically susceptible particles.

 29. The method of claim 21 wherein the method further comprises applying a degreasing agent prior to applying the magnetically susceptible particles.

30 30. The method of claim 21 wherein the method further comprises drying the skin segment prior to applying the magnetically susceptible particles.

35 31. The method of claim 21 wherein the method further comprises applying a vibrational force, such as ultrasound at a frequency of about 10kHz to about 20 kHz,

5 to the skin segment to enhance the penetration of magnetically susceptible particles into the hair follicles.

32. The method of claim 21 wherein the method further comprises applying
a fluid pressure to the skin segment to enhance the penetration of magnetically
10 susceptible particles into the hair follicles.

33. The method of claim 21 wherein the method further comprises applying
a magnetic field to the skin segment to enhance the penetration of magnetically
15 susceptible particles into the hair follicles.

34. The method of claim 21 wherein the method further comprises marking
the skin segment following treatment.

35. An apparatus for devitalizing hair follicles, comprising:
20 means for guiding a magnetic field and for engaging a region of skin; and
means for producing a varying magnetic field and applying the varying
field to the skin through the field guide,
whereby, upon application of magnetically susceptible particles to hair
follicles within the skin and generation of the varying magnetic field, the particles
25 devitalize the hair follicles.

36. The apparatus of claim 35 wherein the apparatus further comprises
means for marking a treated region following treatment.

37. The apparatus of claim 35 wherein the apparatus further comprises
30 means for sensing the proximity of conductive implants that could be adversely affected
by a varying magnetic field.

38. The apparatus of claim 35 wherein the means for producing a time-
35 varying magnetic field is a resonant circuit.

5 39. The apparatus of claim 35 wherein the field guide means is a ferrite structure.

 40. An apparatus for depilating hair, comprising
 means for generating an alternating electric current;
10 means for guiding a magnetic field and for engaging a region of a subject's skin
 an electrically conductive coil structure surrounding at least an portion
 of the field guide means and electrically coupled to the source of alternating current
 through a capacitance, such that the coil and capacitance define a resonant circuit,
15 whereby, upon application of magnetically susceptible particles to hair
 follicles within the skin region and the generation of an electrical current in the coil, a
 varying magnetic field is formed in the gap which heats the magnetically susceptible
 particles to induce depilation.

20 41. A composition for depilating hairs growing on a skin segment,
 comprising a plurality of magnetically susceptible particles having an average size
 sufficient small to allow penetration of at least a portion of said particles into hair shafts
 on said skin segment and further having sufficient magnetic properties to induce
 localized heating in the presence of variable magnetic field following penetration of a
25 hair follicle to devitalizes at least one component of the hair follicle and thereby inhibit
 further hair growth from with said shaft.

 42. The composition of claim 41 wherein the particles have an average
 particle size ranging from about 5 Angstroms to about 100 micrometers in diameter.

30 43. The composition of claim 42 wherein the particles have an average
 particle size ranging from about 50 Angstroms to about 10 micrometers in diameter.

 44. The composition of claim 41 wherein the composition further comprises
35 a lubricant material.

5 45. The composition of claim 44 where the lubricant material is selected
from the group consisting of water, alcohols, aliphatic liquids and surfactants and
combinations thereof.

10 46. The composition of claim 41 wherein the particles are coated with a
lubricating material.

15 47. The composition of claim 46 where the lubricant coating material is
selected from the group consisting of silicones, hyaluronic compositions,
polysaccharides and combinations thereof.

 48. The composition of claim 41 wherein the particles are a dry slurry.

20 49. The composition of claim 41 wherein the composition further comprises
a particle delivery medium that enhances penetration of the particles into the hair shafts.

 50. The composition of claim 41 wherein the particle delivery medium is
selected from the group of air, water, alcohols, oils, emulsions, and combinations
thereof.

25 51. The composition of claim 41 wherein the particle delivery medium
further comprises a semi-solid material that changes viscosity under pressure.

 52. The composition of claim 51 wherein the semi-solid material comprises
a polyvinyl alcohol.

30 53. The composition of claim 41 wherein the particle delivery medium
further comprises a germicidal agent.

35 54. The composition of claim 41 wherein the particle delivery medium
further comprises an electrically charged moiety.

5 55. The composition of claim 41 wherein the particle delivery medium further comprises a material having low surface tension.

 56. The composition of claim 41 wherein the composition further comprises an anesthetic agent.

10 57. The composition of claim 41 wherein the composition further comprises a pore penetration enhancing agent

 58. The composition of claim 41 wherein the particles further comprises a
15 paramagnetic material.

 59. The composition of claim 41 wherein the particles further comprises a iron containing material.

20 60. The composition of claim 41 wherein the particles further comprises magnetite.

 61. The composition of claim 41 wherein the particles further comprise a material having a Curie temperature of at least 45 degrees C.

25 62. The composition of claim 41 wherein the particles further comprise a material Having an initial susceptibility of at least 0.1 EMU/gauss/gFe.

 63. The composition of claim 41 wherein the particles further comprise a
30 material having an initial susceptibility of at least 0.3 EMU/gauss/gFe.

 64. The composition of claim 41 wherein the composition further comprises a colloidal suspension of magnetite, iron or cobalt or alloys or compounds containing such materials.

5 65. The composition of claim 64 wherein the particles are coated with a surfactant.

 66. The composition of claim 41 wherein the particles are coated with an acid surfactant.

10 67. The composition of claim 41 wherein the particles are coated with an electrically charged surfactant.

 68. The composition of claim 41 wherein the particles are coated with a cationic surfactant.

15 69. The composition of claim 41 wherein the particles are coated with an anionic surfactant.

20 70. The composition of claim 41 wherein the particles are coated with a amphoteric surfactant.

 71. An kit for depilating hair, comprising
 a magnetic field guide adapted to engage a region of skin; and
25 a generator for producing a varying magnetic field and applying the
varying field to the skin through the field guide,
 whereby, upon application of magnetically susceptible particles to hair
follicles within the skin and generation of the varying magnetic field, the particles
devitalize the hair follicles.

30 72. The kit of claim 71 wherein the kit further comprises a supply of magnetically susceptible particles.

 73. The kit of claim 71 wherein the kit further comprises an applicator for
35 applying magnetically susceptible particles to a skin region.

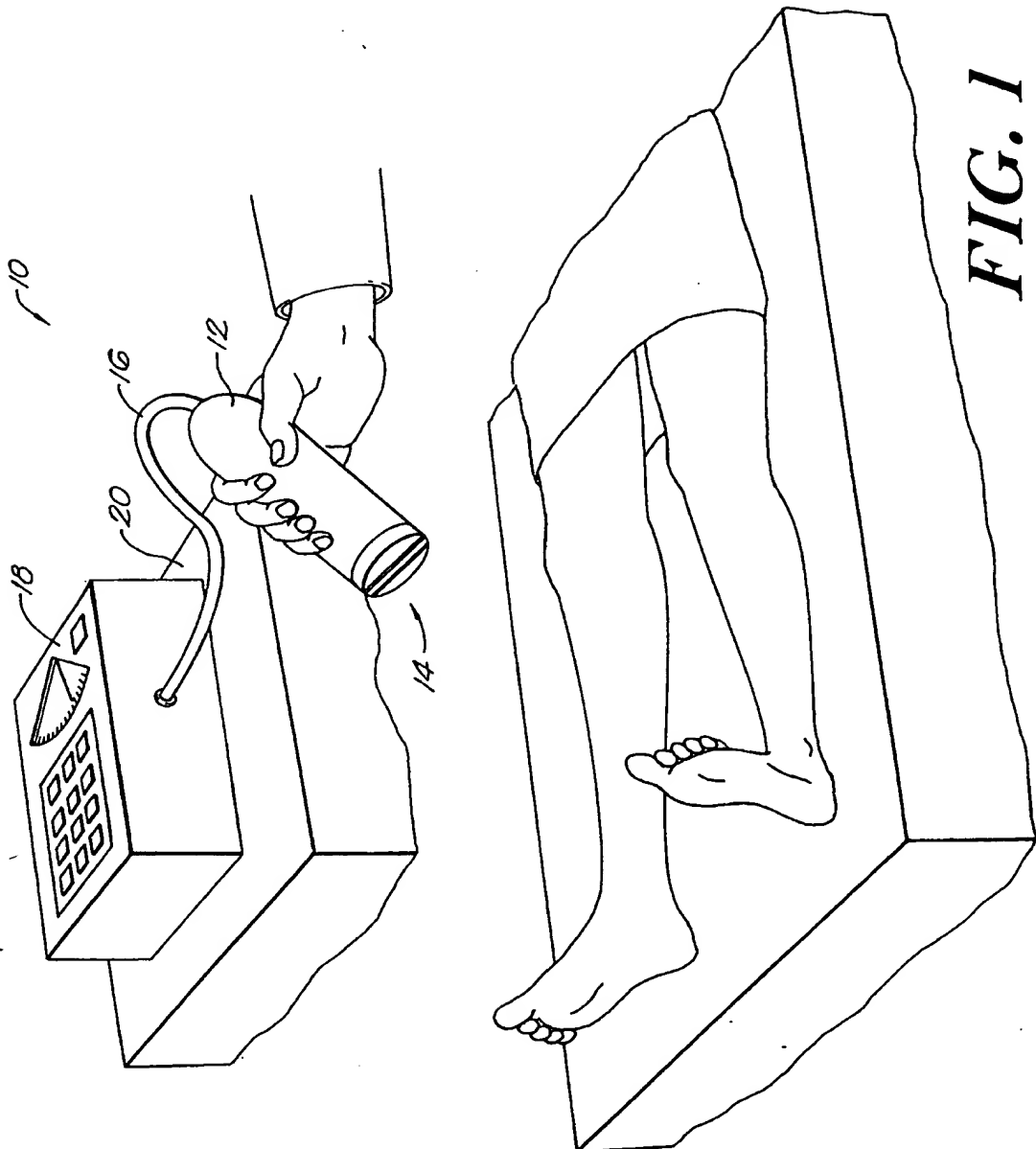
5 74. The kit of claim 73 wherein the kit further comprises a skin penetration
enhancing apparatus.

 75. The kit of claim 71 wherein the kit further comprises a particle removal
apparatus.

10

 76. The kit of claim 71 wherein the kit further comprises a protective shield
for electrically conductive implants.

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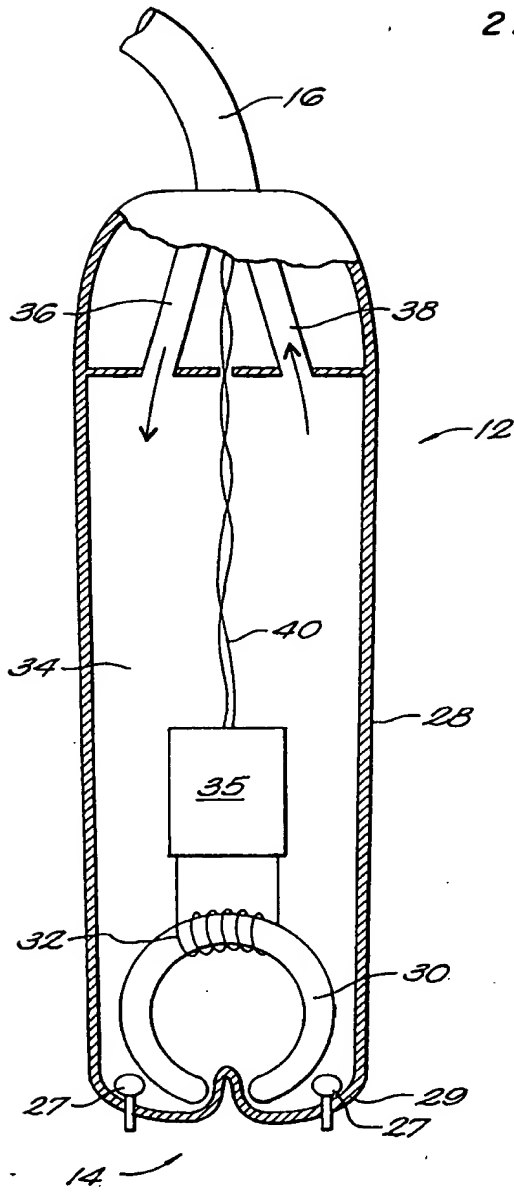


FIG. 2

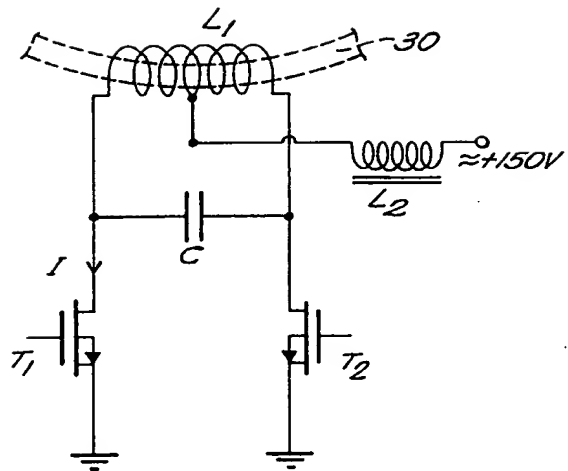


FIG. 3

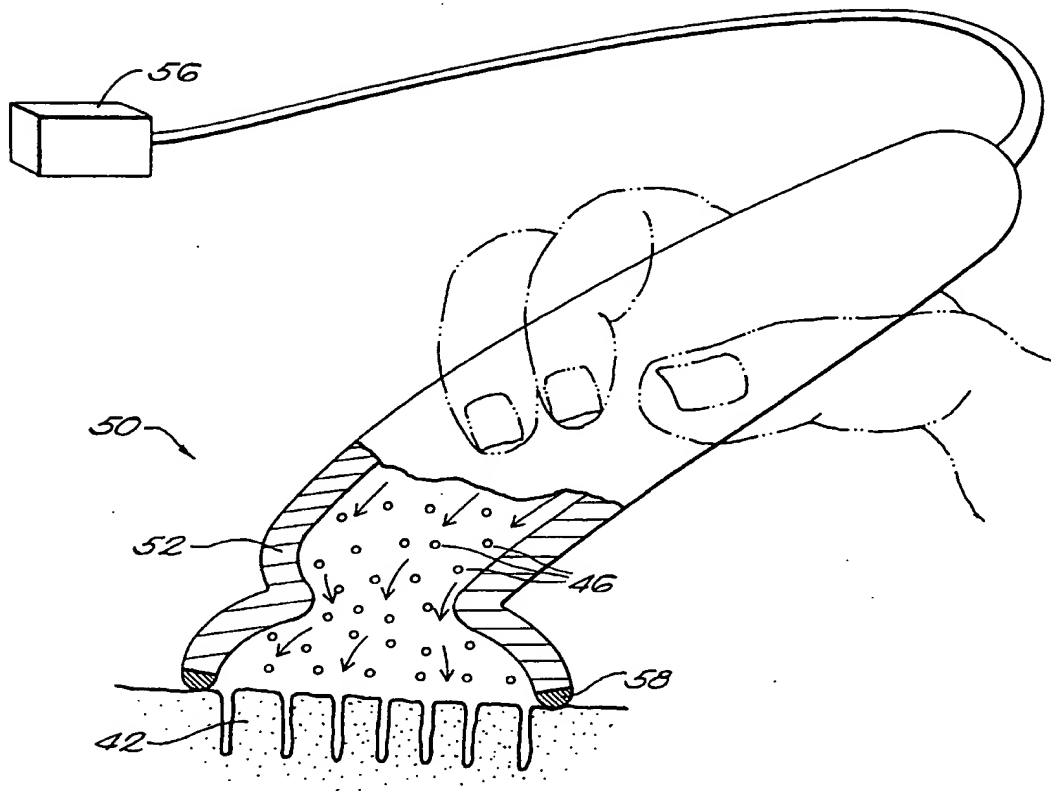


FIG. 5

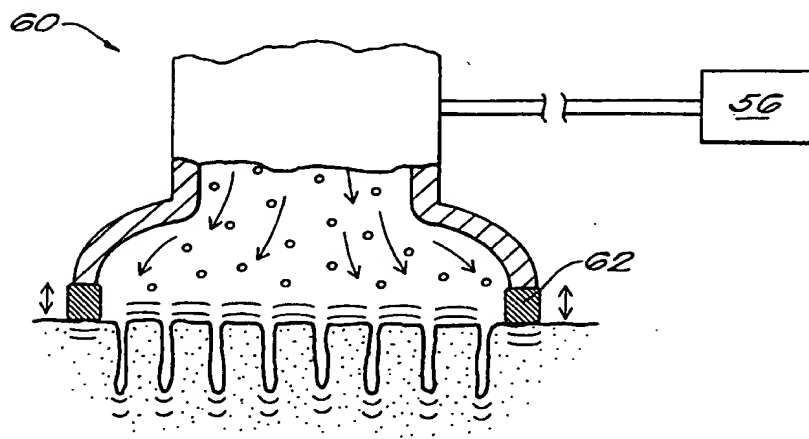
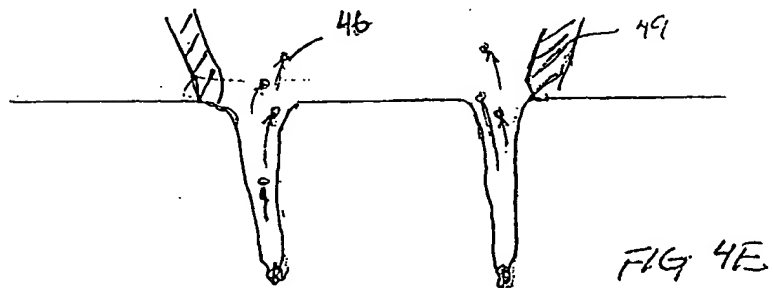
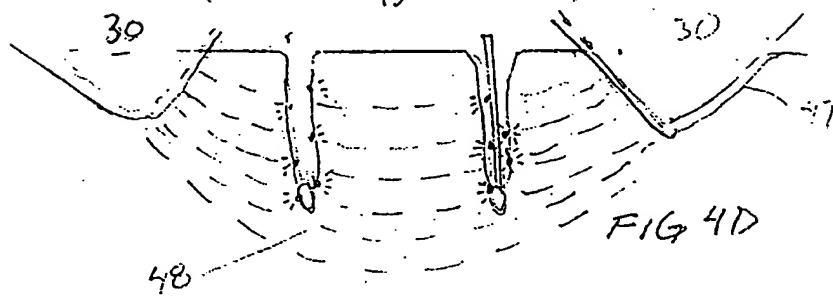
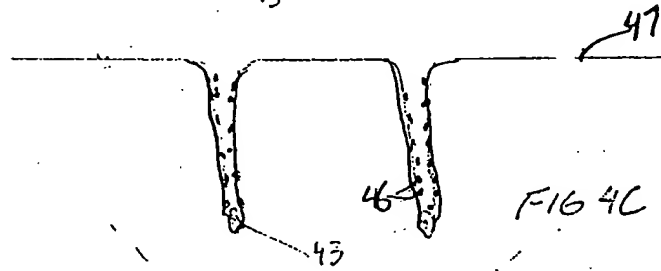
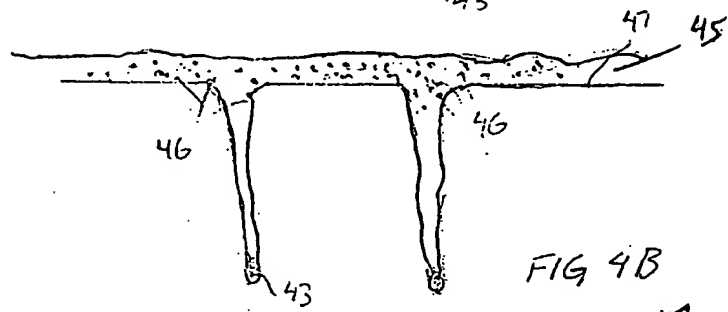
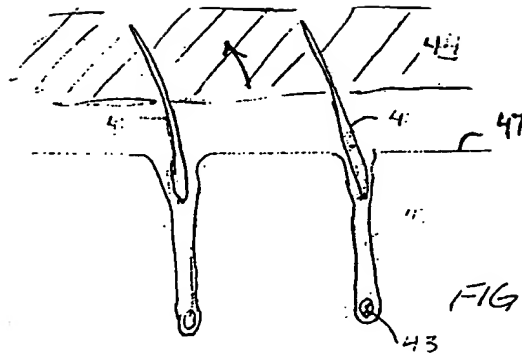


FIG. 6



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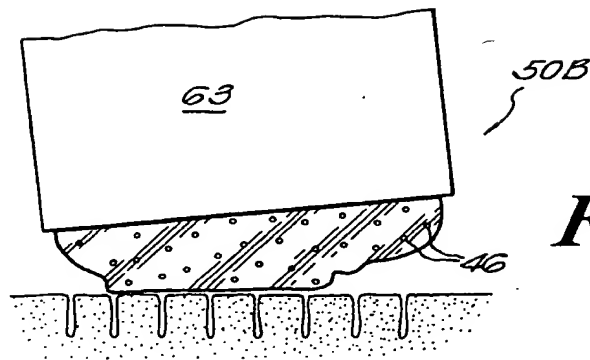


FIG. 7

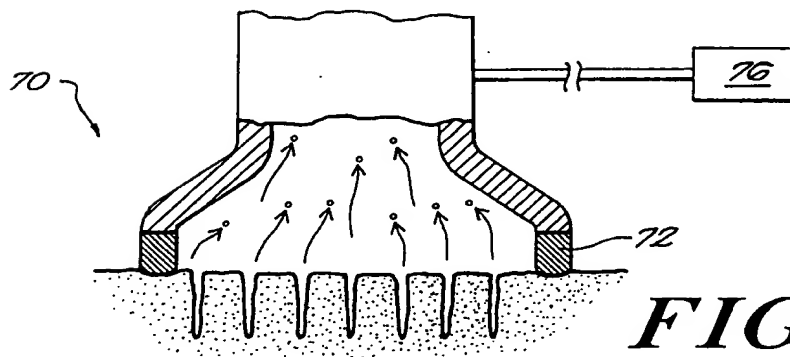


FIG. 8

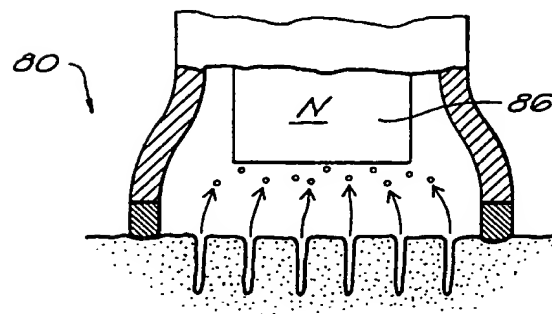


FIG. 9

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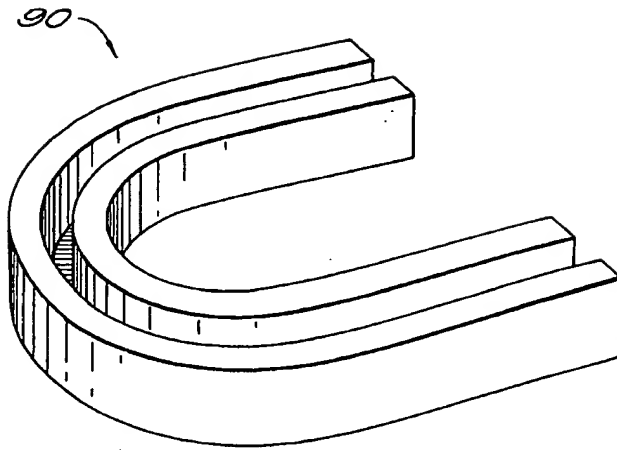


FIG. 10